Great Lakes Supplement

Pictured Rocks National Lakeshore

Millions of years ago, retreating ice sheets carved giant basins into the North American landscape, filling them with glacial meltwater and leaving behind one of the continent's most valuable resources. The Great Lakes and its 5,500 miles of coastline are a life source to more than 40 million people.[1] Containing one-fifth of the world's fresh surface water, these five lakes not only provide drinking water to residents of the region but are also an economic and recreational asset.

Every summer, millions of people flock to the Great Lakes to enjoy its beaches for swimming, boating, fishing, and other outdoor activities. From the uppermost point of Minnesota, down to Michigan and east to New York, these beaches are a destination where generations of Americans have found relief from the summer heat and a place where many have built their lives.

However, the survival of the Great Lakes and our intimate relationship with its waters are under attack by forces outside and within the lakes. From their shores, increasingly violent weather overwhelms crumbling infrastructure, dumping tainted runoff into our precious waters. Under the water's surface, invasive species spread unchecked, decimating the food web and destabilizing the ecosystem, while algal blooms ooze onto beaches. Though efforts are being made to improve the Great Lakes' water quality, clean up their beaches, and slow the growth of invasive species, a lack of data about these pollution sources hinders the creation of a comprehensive action plan. Until these threats are properly addressed, beachgoers will continue to suffer the health risks of swimming in polluted waters, and residents of the Great Lakes region will continue to feel the environmental and economic impacts.

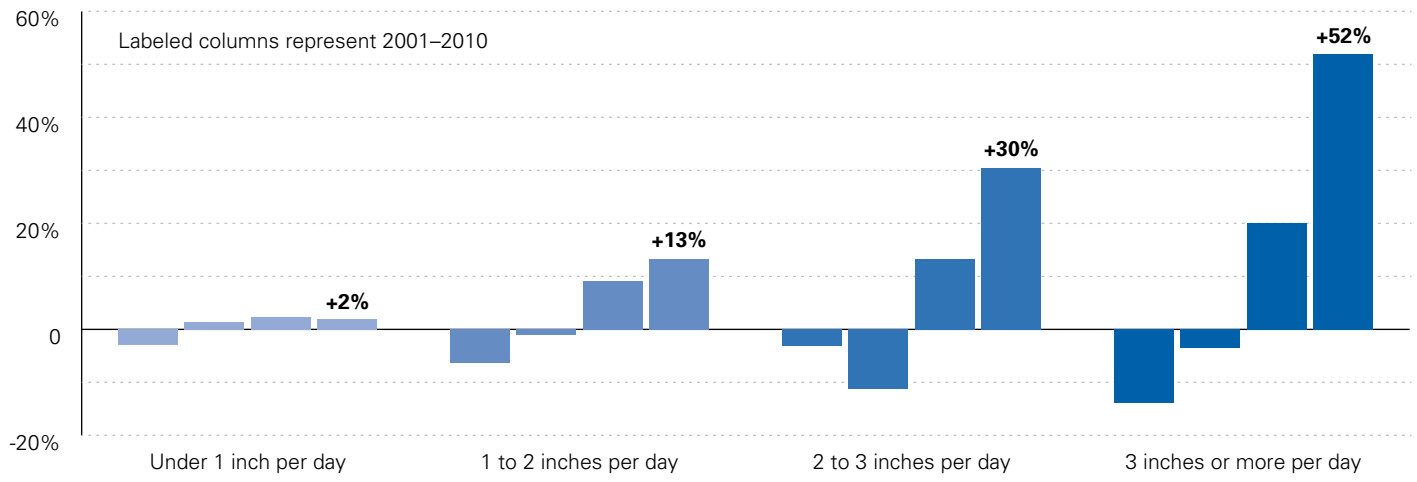
GREAT LAKES STRESSORS

Climate Change

Currently more than 70 percent of all combined sewers in the United States are located in the Great Lakes region.[2] Unlike separated sewer systems, combined sewers collect sanitary sewage and stormwater runoff within a single pipe system and route the mixture to sewage treatment plants. However, heavy rainfall and extreme weather can quickly overwhelm these systems. To prevent sewage from flooding homes and businesses, combined sewer systems send excess flow into local waterways, including the Great Lakes.[3]

Climate change models suggest that extreme storms and rainfall will become stronger and more frequent in the Great Lakes region.[4] In fact, the annual frequency of three-inches-plus storms increased by 103 percent from 1961 through 2011. Storms of at least two inches but less than three inches in a day, the trend was an 81 percent increase; and storms of one to two inches, a 34 percent increase.[5] The frequency of extreme storms has increased so much in recent years that the first 12 years of this century included seven of the nine top years (since 1961) for the most extreme storms in the Midwest.

Figure GL-1: Frequency of Storms by Size in the Midwest
Changes by Decade, 1960s Through 2000s, Compared to 1961–1990



The graph below illustrates the changes by decade in the annual frequencies of different-sized storms over the last five decades. Storms are grouped by days with less than 1 inch of precipitation, at least 1 inch but less than 2 inches, at least 2 but less than 3 inches, and 3 inches or more. In each group, the columns from left to right represent 1961-1970; 1971-1980; 1981-1990; 1991-2000; and 2001-2010.

In southern Wisconsin, extreme precipitation events are expected to become 10 to 40 percent stronger and are likely increase the frequency of CSOs into Lake Michigan by 50 to 120 percent by the end of this century.[6]

Failing Infrastructure

The American Society of Civil Engineers' 2009 Infrastructure Report Card gave the nation's aging wastewater system a grade of D-minus.[7] In the eight Great Lakes states, $71.84 billion in wastewater infrastructure investment is needed over the next 20 years to achieve a basic level of functionality.[8] From 2008 through 2010, Gary, Indiana, alone discharged 6.8 billion gallons of raw and partially treated sewage into waterways that flow directly into Lake Michigan.[9]

In June 2011, the Metropolitan Water Reclamation District of Greater Chicago voted to disinfect wastewater dumped into the Chicago River from two of its treatment plants, finally bringing Chicago in line with other major U.S. cities, virtually all of which have been disinfecting for decades.[10] This decision is a step toward strengthening the water infrastructure at a pivotal point on the Great Lakes coastline as well as improving water quality in the Chicago River. Nevertheless, the Chicago region's combined sewer systems continue to dump large volumes of untreated sewage into the river, reflecting the larger failure of wastewater infrastructure in the Great Lakes region and across the nation. The combination of failing infrastructure and more extreme weather events sets the stage for a bleak future in which CSOs continue to dump raw sewage into the Great Lakes and onto its beaches.

Runoff Pollution

In addition to point-source pollution—pollution that comes from a single location, such as a municipal wastewater treatment plant—the Great Lakes is also under siege by non-point-source (runoff) pollution, which comes from multiple and often diffuse sources and is much more difficult to identify. Stormwater and irrigation runoff from urban and agricultural areas carry sediment and fertilizers (which contain nitrogen and phosphorus) into the Great Lakes, adding to the already heavy load of nutrients being discharged by sewage treatment plants and other point sources.[11] Nitrogen and phosphorus serve as food for aquatic plants such as algae and catalyze their overproduction.[12] These algae are suffocating the Great Lakes by creating a condition called hypoxia, a depletion of oxygen levels in the water as they grow and later as they decompose.[13] Similar to the "dead zone" in the Gulf of Mexico, the Great Lakes' aquatic environment and beaches are slowly dying, unable to sustain the biological diversity they once had.

HEALTH IMPACTS

Despite the vast size of the Great Lakes, the discharge of billions of gallons of untreated sewage into its waters has a significant impact on human health. Untreated sewage can contain more than 120 viruses. Two of these viruses, *Giardia* and *cryptosporidium*, can cause intestinal illnesses and even death.[14] Stormwater adds to this toxic soup as it runs over impervious surfaces such as roads, roofs, and parking lots, picking up fecal matter, pesticides, and other pollutants before flowing into sewers. These viruses and pollutants don't simply disappear under the lakes' surface. A study in Door County, Wisconsin, demonstrated that at six out of eight Lake Michigan beaches, there was a significant association between rainfall and elevated concentrations of *E. coli* in the water.[15]

Despite the severity of these health risks, a new EPA proposal concerning U.S. beach pollution fails to address them. The EPA is required under the Beaches Environmental Assessment and Coastal Health (BEACH) Act of 2000 to issue recreational beach standards that are "necessary for the protection of public health and safety." However, the agency has proposed recreational beach criteria at a level that would allow 1 in 28 people to get sick when they visit the beach.[16,17]

E. coli

E. coli concentrations, as well as concentrations of enterococcus, are bacterial indicators of fecal contamination in water, which can make swimmers sick. Under the BEACH Act, seven of the eight Great Lakes states use a single-sample *E. coli* standard to determine beach closing and advisory decisions.[18] Elevated concentrations of *E. coli* and enterococcus routinely force beach closures in the Great Lakes region. However, these closings cannot be attributed only to CSOs and stormwater runoff.

Algae

Nitrogen and phosphorus in stormwater runoff, sewage from CSOs and water treatment plants, and agricultural runoff spur the growth of large, harmful algal blooms (HABs). These blooms have grown so rampantly in the Great Lakes that they can be seen from space.[19] HABs foul beaches and the taste of drinking water as well as produce toxins that are dangerous to humans and wildlife.

Acute exposure to the hepatotoxin microcystin, which is produced by cyanobacteria (blue-green algae), can lead to gastrointestinal illness, and chronic exposure can result in liver disease and damage and possible tumor promotion. In some parts of Lake Erie, explosive growth of cyanobacteria has made the water so toxic that people are warned not to let their pets drink it.[20] At an inland lake in Ohio, nine people became ill and at least three dogs died after coming in contact with the algae.[21] Unfortunately, monitoring HABs and their toxins is difficult, and methods for doing so are still under development.[22] Only a few emerging observation systems in marine and freshwater environments include HAB-specific instrumentation, and none of the Great Lakes states currently have HAB monitoring in place to protect swimmers.[23]

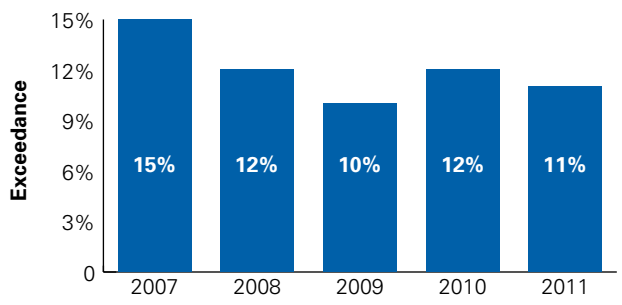
Temperature increases associated with climate change, including both rising overall temperatures and more extreme temperature fluctuations,[24] also contribute to nutrient-fueled algal growth in the Great Lakes. Cladophora, a green alga found in the Great Lakes, thrives in warmer temperatures. May 2011 to April 2012 was the warmest May-to-April period in the contiguous United States, with an average temperature 2.8°F higher than the 20th-century average.[25] Due to the abnormally mild winter, scientists have warned that there could be more beach closures due to the early proliferation of the smelly, slimy algae.[26] Clumps of cladophora can be breeding grounds for bacteria such as *E. coli* and enterococcus, creating high pathogen counts and triggering beach closures.[27]

Invasive Species and Algal Mats

Another force abetting in the growth of algae is the decimating impact of invasive species, such as quagga and zebra mussels. Introduced into the Great Lakes ecosystem via ballast water from oceangoing freighters, these filter-feeders have significantly eliminated the abundance of phytoplankton and other microorganisms in the Great Lakes. One study found that fish biomass has decreased by about 95 percent in Lake Huron and significantly in Lake Michigan due to zebra and quagga mussels' filtering out plankton at the base of the food chain.[28] While increased water clarity may sound like an improvement, a cloudy lake is actually a healthy lake. Sunlight, able to penetrate the water, encourages the growth of large mats of green algae on the lake floor.[29] These mats can break free and eventually accumulate on beaches, fouling the coasts.[30]

Unfortunately, the problem of invasive species and algae in the Great Lakes has the potential to worsen. If the tireless filter-feeding Asian carp is able to gain access to the lakes from waterways in and around Chicago, the effects could be devastating. The carp have the potential to clarify lake water to the point of an ecosystem collapse, leading not only to extreme environmental consequences but to high economic costs as well. A report commissioned and released by The Nature Conservancy estimates that the region is spending more than $100 million annually to manage the effects of invasive species in the Great Lakes on businesses and consumers.[31]

Figure GL-2: Percent of samples exceeding the recommended single-sample maximum *E. coli* standard for designated beach areas for 426 beaches reported in the Great Lakes each year from 2007-2011



Bacteria in Great Lakes Beachwater

NRDC conducted a comparative analysis of water quality at beaches along the U.S. Great Lakes shoreline using publicly available monitoring data from all eight Great Lakes states. In 2011, 595 beaches were monitored on at least a weekly basis.

Eleven percent of all beachwater samples collected in 2011 exceeded the BEACH Act's single-sample maximum *E. coli* standard for designated freshwater beaches (a density of 235 cfu per 100 ml of water). These elevated levels indicate the potential presence of human or animal waste in the water that could make swimmers sick. Over the five-year period during which NRDC has conducted this analysis of Great Lakes beaches, 10 percent to 15 percent of samples at the 426 beaches that reported monitoring data for each year had indicator bacteria levels worse than national recommended standards for designated beach areas—a figure well above the national average.

Table GL-1: Great Lakes beaches with frequent exceedances of the national standard

State	County	Beach	Tier	Monitoring Frequency	Total Samples	Percent Exceedance Rate
MN	St Louis	Park Point 20th Street / Hearding Island Canal Beach	1	2/wk	63	63%
IL	Cook	Winnetka Elder Park Beach	1	Daily	82	54%
MI	Macomb	St. Clair Shores Blossom Heath Beach	1	2/wk	120	53%
OH	Erie	Edson Creek	1	4/wk	52	52%
OH	Lorain	Lakeview Beach	1	Daily	95	51%
OH	Cuyahoga	Edgecliff Beach	2	1/wk	16	50%
OH	Cuyahoga	Villa Angela State Park	1	Daily	111	50%
WI	Douglas	Wisconsin Point Beach 2	3	1/wk	43	49%
IN	Lake	Jeorse Park Beach I	2	5/wk	65	48%
OH	Cuyahoga	Moss Point Beach	2	1/wk	19	47%
OH	Cuyahoga	Sims Beach	2	1/wk	19	47%
OH	Cuyahoga	Arcadia Beach	2	1/wk	18	44%

Great Lakes Beach Closings/Advisories and Pollution Sources

- During 2011, U.S. Great Lakes beaches had 3,410 days of closings and advisories, along with 4 extended (248 days total) and 3 permanent (334 days total) closings and advisories. Extended closings and advisories last more than 6 but not more than 13 consecutive weeks, and permanent closings and advisories last more than 13 consecutive weeks. Including extended days, the total comes to 3,658 beach closing and advisory days.
- The number of beach closing and advisory days decreased 9 percent from 3,766 days in 2010.
- The continued high level of closings/advisories is an indication that frequent monitoring continues to reveal serious water pollution at our nation's Great Lakes beaches.

Major reasons for beach closings and advisories in 2011 were as follows: (Note: Because of inconsistencies in monitoring and closing/advisory practices among states and the different levels of data submission over time, it is difficult to make comparisons between states or to assess trends on the basis of closing/ advisory data.)

- 91 percent (3,098 days) were based on monitoring that detected bacteria levels exceeding beachwater quality standards, compared with 84 percent (3,176 days) in 2010;
- 5 percent (174 days) were precautionary due to rainfall runoff, compared with 7 percent (276 days) in 2010;
- 3 percent (101 days) were due to other, unspecified causes, compared with 3 percent (106 days) in 2010;
- 2 percent (6 days) were issued in response to known pollution events, such as sewage treatment plant failure or breaks in sewage pipes, compared with 4 percent (135 days) in 2010; and
- 1 percent (34 days) were preemptive due to real-time computer modeling that used readily measurable physical parameters such as wind speed and wave height to predict indicator bacterial levels, compared with 1 percent (33 days) in 2010.

Major pollution sources listed as responsible for 2011 beach closings and advisories included the following:

- Unknown sources of pollution caused 2,724 closing/advisory days (80 percent of the year's total), compared with 3,143 days (83 percent) in 2010;
- polluted runoff and stormwater caused or contributed to 528 closing/advisory days (15 percent of the year's total), compared with 351 days (9 percent) in 2010;
- sewage spills and overflows caused or contributed to 93 closing/advisory days (3 percent of the year's total), compared with 64 days (2 percent) in 2010; and
- elevated bacteria levels from miscellaneous sources (wildlife, boat discharges, etc.) accounted for 60 closing/advisory days (2 percent of the year's total), compared with 208 days (6 percent) in 2010.

Bacterial Standards

Seven of the eight Great Lakes states use the national recommended single-sample standard for designated beach areas to inform beach closing/advisory decisions. This standard is 235 cfu/100 ml of *E. coli*. Michigan's single-sample standard is 300 cfu/100 ml of *E. coli*.

Minnesota applies the national recommended geometric mean standard of 126 cfu/100 ml, and Michigan applies a geometric mean standard of 130 cfu/100 ml. Pennsylvania applies the national recommended geometric mean standard of 126 cfu/100 ml to swimming restrictions only, while Wisconsin may use the same standard to make closing/advisory decisions at high-priority beaches. Illinois, Indiana, and Ohio do not apply the geometric mean standard when making closing and advisory decisions. In New York, local beach authorities decide whether to apply the geometric mean when making closing and advisory decisions.

Economic Impacts

If the Great Lakes–St. Lawrence River region (including the U.S. and Canada) were its own country, it would be the fourth-largest economy in the world.[32] More than 1.5 million jobs in the U.S. are directly tied to the Great Lakes, with 200,000 jobs supported by recreation and tourism. Accordingly, the damage inflicted on the Great Lakes has not only severe environmental and human health impacts, but wide-reaching economic effects as well. Zebra and quagga mussels impact power plants, municipal water supplies, and other industries by clogging water intake pipes. Coastal communities and businesses that depend on native fish populations have also been hit hard by the rise in invasive species. In 2009 alone, chinook salmon fisheries brought more than $32 million into Great Lakes communities. However, the Michigan Department of Natural Resources estimates that 10 ports in Michigan have lost more than $19 million in economic activity since 2004 because of drops in the chinook salmon population due to invasive species.[33]

Economic costs aren't limited to fishing, power plants, and municipal water supplies. While boating and spending days at the beach may sound like only fun and games, they have a significant impact on the economy of the region. In 2003, spending on boats and boating activities in the Great Lakes states totaled nearly $16 billion and directly supported 107,000 jobs.[34] If the threats of failing infrastructure, invasive species, and algal blooms continue unaddressed, there will be severe repercussions for local economies. Closing all the beach sites on Lake Michigan could cause a loss as high as $2.7 billion.[35] According to a 2006 study, the estimated loss in societal benefits because of invasive species alone may be a staggering $200 million per year.[36]

Recommendations for Great Lakes Communities

- Invasive species are a serious threat to the health of the Great Lakes. The most common pathway by which invasive species are introduced to the Great Lakes is the ballast water used to stabilize large commercial vessels. In 2012, after more than a decade of debate, the Coast Guard established the nation's first ballast water discharge standards, meant to prevent invasive species from slipping into American waters. Unfortunately, the standard is flawed. It is based on International Maritime Organization standards, which are not strict enough to ensure that invasive species are not introduced or spread throughout the nation's waters. It gives ships until 2021 to put ballast water controls in place, and it fails to articulate a more protective standard to drive the development of better treatment methods and technologies. Fortunately, the U.S. Environmental Protection Agency and the states still have an opportunity to put stronger standards in place under the Clean Water Act. EPA and the states should establish standards strong enough to fully protect our waters by preventing invasive species from being established in the first place.

- While ballast water is the most common source of invasive species, it is far from the only one. The imminent invasion of Asian carp, moving from the Mississippi River through the Chicago River system and into Lake Michigan, continues to require swift and coordinated action from an array of engaged authorities. The introduction of carp into the Great Lakes could exacerbate the damage already under way by further clarifying the water and eliminating native species, both of which allow proliferation of algae and organisms dangerous to human health. This is why NRDC continues to advocate for a physical separation of the Great Lakes Basin and Mississippi River system in the Chicago-area waterways that connect the two great ecosystems. It has become clear that the Army Corps of Engineers is incapable of developing solutions with the urgency needed to address this threat. The Senate's Stop Invasive Species Act of 2012, cosponsored by senators from across the Basin, with a companion House bill, will help to jump-start the development of real long-term solutions to the invasive species crisis.

- In 2008, the Great Lakes-St. Lawrence River Basin Water Resources Compact was signed into law, requiring the eight Great Lakes states, along with Ontario and Quebec through a companion agreement, to prevent the diversion of Great Lakes and St. Lawrence waters outside of the Basin, and to manage the withdrawal and use of water within the Basin efficiently. States must fully implement all provisions of the Compact by December 2013. Among other things, the Compact requires states to consider opportunities to integrate green infrastructure solutions into long-term planning. States must ensure they implement all of the key provisions of the Compact, including its recognition of the importance of tributary health to the health of the Great Lakes themselves.

- Full funding of Great Lakes restoration and collaboration initiatives will allow the EPA to continue to support research and habitat restoration in the region to help stem the impacts of invasive species and improve beach and lake water quality through support for beach monitoring, CSO improvements, and green infrastructure. In 2012, President Obama pledged to extend funding for the Great Lakes Restoration Initiative, an interagency program established in 2010 to improve the health and quality of the Great Lakes by providing grants to conservation groups in the region.[37]

- Residents throughout the Great Lakes region have a critical role to play: adding water efficiency and green infrastructure features to their homes and workplaces. Rain gardens and rain barrels capture water where it falls, reducing the amount of flow to sewer systems. Planting trees and native plants, participating in beach cleanups, and practicing simple water conservation techniques—such as turning off the water while brushing one's teeth—all have significant impacts on the local water footprint and help avoid polluting our lakes and beaches.

Endnotes

1 Hinderer, Julie M., and Michael W. Murray, "Feast and Famine in the Great Lakes: How Nutrients and Invasive Species Interact to Overwhelm the Coasts and Starve Offshore Waters," National Wildlife Federation, 2011, www.nwf.org/~/media/PDFs/Regional/Great-Lakes/GreatLakes-Feast-and-Famine-Nutrient-Report.ashx.

2 Great Lakes Commission, "The Federal Wastewater Infrastructure Deficit in the Great Lakes Region," 2010, www.glc.org/announce/10/pdf/CitiesInvest-20100212-Final.pdf.

3 Great Lakes Commission, op. cit.

4 Stephen Saunders et al (May 2012). "Doubled Trouble: More Midwestern Extreme Storms," Rocky Mountain Climate Organization and Natural Resources Defense Council, http://rockymountainclimate.org/images/Doubled%20Trouble.pdf.

5 Saunders et al, p. i.

6 Patz, Jonathan A., "Climate Change and Waterborne Disease Risk in the Great Lakes Region of the U.S." *American Journal of Preventative Medicine*: 35 (5), 2008, www.sage.wisc.edu/pubs/articles/M-Z/patz/patzetalAJPM08.pdf.

7 American Society of Civil Engineers, "Wastewater," Report Card for America's Infrastructure, 2009, www.infrastructurereportcard.org/fact-sheet/wastewater.

8 Great Lakes Commission, op. cit.

9 "Gary Sanitary District Dumped Billions of Gallons of Sewage," CBS Chicago, January 31, 2011, chicago.cbslocal.com/2011/01/31/gary-sanitary-district-dumped-billions-of-gallons-of-sewage/.

10 Lydersen, Kari, "MWRD Votes to Disinfect Chicago River Sewage," Chicago News Cooperative, June 7, 2011, www.chicagonewscoop.org/chicago-river-sewage-will-be-disinfected-after-landmark-vote/.

11 U.S. Environmental Protection Agency, "The Great Lakes," The Great Waters Program, 2011, www.epa.gov/oaqps001/gr8water/xbrochure/lakes.html.

12 Stern, Andrew, "Great Lakes Face Stresses from Run-Off Invaders," Reuters, October 4, 2011, www.reuters.com/article/2011/10/04/us-greatlakes-idUSTRE7937CY20111004.

13 Yeoman, Barry, "Lake Erie Deathwatch," *OnEarth*, August 31, 2011, www.onearth.org/article/lake-erie-death-watch.

14 "Turning the Tide: Investing in Wastewater Infrastructure to Create Jobs and Solve the Sewage Crisis in the Great Lakes," Healing Our Waters—Great Lakes Coalition, 2010, healthylakes.org/wp-content/uploads/2010/08/08-02-2010HOWSewageReportFINAL.pdf.

15 Kleinheinz, Gregory, et al., "Effects of Rainfall on E. coli Concentrations at Door County, Wisconsin Beaches," *International Journal of Microbiology*, Vol. 9, 2009.

16 U.S. EPA, Office of Water, "Beaches Environmental Assessment and Coastal Health Act of 2000," BEACH Act, 2000, water.epa.gov/lawsregs/lawsguidance/beachrules/act.cfm.

17 Fleischli, Steve, "EPA Proposal Allows 1 in 28 People to Get Sick at U.S. Beaches," NRDC Switchboard, January 30, 2012, switchboard.nrdc.org/blogs/sfleischli/epa_proposal_allows_1_in_28_pe.html .

18 U.S. EPA, Office of Water, "Bacterial Water Quality Standards for Recreational Waters (Freshwater and Marine Waters) Status Report," EPA-823-R-03-008, 2003, water.epa.gov/type/oceb/beaches/upload/2003_06_19_beaches_local_statrept.pdf.

19 Cmar, Thom, "NRDC Taking Legal Steps to Protect the Great Lakes from Toxic Algal Blooms," NRDC Switchboard, March 14, 2012, switchboard.nrdc.org/blogs/tcmar/nrdc_taking_legal_steps_to_pro.html.

20 Pollick, Steve, "Keep an Eye on Canine Pals Around Lake," *Toledo Blade*, October 9, 2010, www.toledoblade.com/StevePollick/2010/10/10/Keep-an-eye-on-canine-pals-around-lake.html .

21 Hunt, Spencer, "Algae May Be Killing Pets," *The Columbus Dispatch*, August 2, 2010, www.dispatch.com/content/stories/local/2010/07/30/algae-may-be-killing-pets.html.

22 Erdner, Deana L., et al., "Centers for Ocean and Human Health: A Unified Approach to the Challenge of Harmful Algal Blooms," *Environmental Health*, 7 (Suppl 2):S2, 2008, www.ehjournal.net/content/7/S2/S2.

23 Magnien, Robert, "Harmful Algal Blooms and Hypoxia in the Great Lakes Region," National Centers for Coastal Ocean Science, 2009, www.cop.noaa.gov/stressors/extremeevents/hab/habhrca/GL_fact_09.pdf.

24 Saunders, Stephen, et al., "Great Lakes National Parks in Peril: The Threats of Climate Disruption," Rocky Mountain Climate Organization and Natural Resources Defense Council, July 2011, rockymountainclimate.org/images/GreatLakesParksInPeril.pdf.

25 National Oceanic and Atmospheric Administration, "U.S. Temperatures for April Third Warmest on Record," April 2012, www.ncdc.noaa.gov/sotc/summary-info/national/2012/4.

26 Bienkowski, Brian, "Using Spring Temperatures to Predict Summer Slime," Great Lakes Echo, May 1, 2012, greatlakesecho.org/2012/05/01/using-spring-temperatures-to-predict-summer-slime/.

27 U.S. Geological Survey, Great Lakes Science Center, "Algal (Cladophora) Mats Harbor High Concentrations of Indicator Bacteria and Pathogens," GLSC Fact Sheet 2009-1, greatlakesbeaches.usgs.gov/publications/2009-1%20Cladophora.pdf.

28 Pelley, Janet, "Musseling Out Algae," *Chemical & Engineering News*, March 30, 2011.

29 Hinderer and Murray, op. cit.

30 Heuvel, Amy V., et al., "The Green Alga, *Cladophora*, Promotes *Escherichia coli* Growth and Contamination of Recreational Waters in Lake Michigan," *Journal of Environmental Quality*, Vol. 39, No. 1, 2009, p. 333-344, www.agronomy.org/publications/jeq/articles/39/1/333.

31 Anderson Economic Group LLC, "The Costs of Aquatic Invasive Species to Great Lakes States," The Nature Conservancy, 2012, www.nature.org/ourinitiatives/regions/northamerica/areas/greatlakes/ais-economic-report.pdf.

32 World Business Chicago, "Great Lakes and St. Lawrence Region," 2011, www.worldbusinesschicago.com/files/data/GLSL_Economy_Update_2011%20(2009%20data)_1.pdf.

33 Hinderer and Murray, op. cit.

34 Great Lakes Commission, "Great Lakes Recreational Boating's Economic Punch," www.glc.org/recboat/pdf/rec-boating-final-small.pdf.

35 Song, Feng, Frank Lupi, and Michael Kaplowitz, "Valuing Great Lakes Beaches," prepared for presentation at the Agricultural and Applied Economics Association Join Annual Meeting, July 2010, ageconsearch.umn.edu/bitstream/61791/2/BeachPaper-Submit-10May5.pdf.

36 Lodge, David, and David Finnoff, "Annual Losses to Great Lakes Region by Ship-borne Invasive Species at Least $200 Million," Great Lakes United, 2006, www.glu.org/en/system/files/lodge_factsheet.pdf.

37 Great Lakes Restoration, glri.us/.